the power of light

Choosing the right detector is key to accurate beam power measurements.

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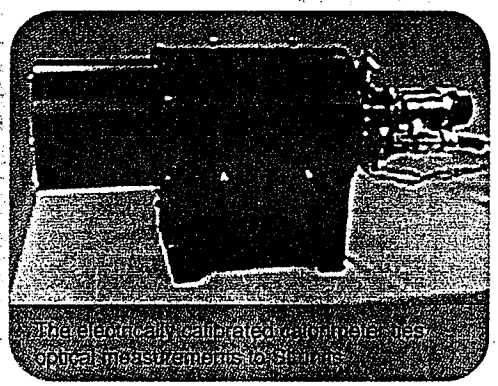
Whether it be optical lithography or micromachining of small structures, lasers are finding their way into an increasingly diverse number of industrial applications. As this expansion continues, laser metrology, such as beam power and energy, will become ever more important for improved in-line process control, increased yields, and laser safety.

Let's consider laser metrology for optical lithography, for example. In a typical lithographic stepper, an excimer laser source illuminates a photomask via sophisticated projection optics, which project a circuit pattern onto a silicon wafer coated with an ultraviolet- (UV) sensitive photoresist. The resolution of the tool is proportional to the wavelength of the source divided by the numerical aperture of the projection optics. The numerical aperture describes the angular spread of light that reaches the wafer plane.



The electrically calibrated calorimeter realizes optical measurements to SI units.

A number of laser measurements are important for both tool development and performance. Measurements at the source are used as part of a feedback mechanism to stabilize the source's pulse energy. As with photography, overexposure or underexposure leads to reduced image contrast and poor resolution. An optimum laser dose will lead to the best resolution of small features at the wafer plane. Optical material characterization measurements, such as transmittance and birefringence, are important for tool development and performance as well. For this article, however, we will limit the discussion to laser power and energy measurements.

Before you purchase a detector for laser power and energy measurements, you must ask yourself several questions:

Is the detector designed to measure laser power or energy, and do you want to measure individual or average pulse energy?
You can measure average pulse energy with a power meter if you know the repetition rate of your laser and the number of pulses measured. In general, power meters are slower than energy meters, however. Also consider the power and energy range of interest in your selection. Some detectors are linear over a wider range of laser power and/or energies than others.

Is the laser pulsed or continuous-wave (cw)?
Some detectors, such as pyroelectric detectors, are only sensitive to pulsed sources. Keep in mind that although a pulsed- and a cw-laser may have the equivalent average power, you should take into account the peak power of a pulsed laser when determining whether or not you will exceed a detector's damage threshold.

Are spatial and angular uniformity important to your measurements?
Spatial nonuniformities can lead to reproducibility problems if your beam size is small relative to the size of the detector. Angular uniformity can be critical in applications that use diverging laser beams.

Will you be using this detector at several laser wavelengths?
If so, you should choose a detector with a spectrally flat response or one in which the calibration factor is specified at the wavelengths of interest.

What level of accuracy is important to your application?
Most commercial detectors are not electrically calibrated; some detectors will detect only a fraction of the incident light because they have reflective surfaces. One can correct for the reflective losses by calibrating the detector against a primary standard or by measuring the surface reflectance. At NIST we have developed primary standard calorimeters for laser power and energy measurements. These electrically calibrated calorimeters directly compare optical and electrical energy, thus tying optical measurements to SI units. The measurement uncertainty associated with these calorimeters is less than 1%. However, measurements made with these calorimeters are time-consuming and difficult.

You must consider the trade-off between accuracy and throughput in the detector selection process. For some applications, only the relative change in laser power or energy is important. Therefore, long-term stability rather than absolute accuracy should be your primary consideration in detector selection.

Although there are many issues to take into consideration when selecting a detector for laser power and energy measurements, by carefully evaluating your needs, you can avoid performing the wrong measurement for your application. **oe**

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